NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

MBA PROFESSIONAL REPORT

Making the Surface Fleet Green:
The DOTMLPF, Policy, and Cost Implications of Using Biofuel in Surface Ships

---

By: Calvin S. Beads, III
December 2012

Advisors: Daniel Nussbaum,
William Fast

Approved for public release; distribution is unlimited

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704–0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202–4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704–0188) Washington, DC 20503.			
1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** December 2012	**3. REPORT TYPE AND DATES COVERED** MBA Professional Report	
4. TITLE AND SUBTITLE Making the Surface Fleet Green: The DOTMLPF, Policy, and Cost Implications of Using Biofuel in Surface Ships			**5. FUNDING NUMBERS**
6. AUTHOR(S) Calvin S. Beads, III			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943–5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol number ____N/A____.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited			**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200 words)

One of the goals of the Department of the Navy's (DON) alternative energy initiative is to reduce the Navy's dependence on fossil fuel. This project uses DOTMLPF criteria to measure the impact of biofuel use on the Surface Fleet. It provides analysis and recommendations for using replacement drop-in biofuels onboard surface ships based on materiel, maintenance, training, infrastructure, logistics, policy, and cost implications.

14. SUBJECT TERMS Biofuel, Alternative Energy, DOTMLPF, Surface Warfare, Petroleum, F-76, HRD-76, Drop-in Replacement Biofuel			**15. NUMBER OF PAGES** 61
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540–01–280–5500

Standard Form 298 (Rev. 2–89)
Prescribed by ANSI Std. 239–18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

MAKING THE SURFACE FLEET GREEN:
THE DOTMLPF, POLICY, AND COST IMPLICATIONS OF USING BIOFUEL IN SURFACE SHIPS

Calvin S. Beads, III
Lieutenant, United States Navy
B.A., Morehouse College, 2007

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
December 2012

Authors: ______________________________
Calvin S. Beads, III

Approved by: ______________________________
Daniel Nussbaum, Lead Advisor

____
William Fast, Support Advisor

____
William R. Gates, Dean
Graduate School of Business and Public Policy

THIS PAGE INTENTIONALLY LEFT BLANK

MAKING THE SURFACE FLEET GREEN: THE DOTMLPF, POLICY, AND COST IMPLICATIONS OF USING BIOFUEL IN SURFACE SHIPS

ABSTRACT

One of the goals of the Department of the Navy's (DON) alternative energy initiative is to reduce the Navy's dependence on fossil fuel. This project uses DOTMLPF criteria to measure the impact of biofuel use on the Surface Fleet. It provides analysis and recommendations for using replacement drop-in biofuels onboard surface ships based on materiel, maintenance, training, infrastructure, logistics, policy, and cost implications.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

AFFF	Aqueous Film Forming Foam
ATA	Air Transport Association of America
BCA	Business Case Assessment
BS&M	Bottom Sediment and Water
CG	Guided Missile Cruiser
CONUS	Continental United States
CSG	Carrier Strike Group
CVN	Aircraft Carrier, Nuclear
CVW	Carrier Air Wing
DD	Spruance Class Destroyer
DDG	Guided Missile Destroyer
DFSP	Defense Fuel Supply Point
DLA	Defense Logistics Agency
DoD	Department of Defense
DOE	Department of Energy
DON	Department of the Navy
DOTMLPF	Doctrine, Organization, Training, Materiel, Logistics, Personnel, Facilities
DPA	Defense Production Act
EIA	United States Energy Information Agency
F-76	Military Marine Diesel Fuel
FFG	Guided Missile Frigate
FFP	Fit-for-Purpose Testing
FLC	Fleet Logistics Center
FT S-5	Fischer-Tropsch S-5
FY	Fiscal Year
GSG	Green Strike Group
HFP	Hepatafluoropropane
HRD-76	Hydroprocessed Renewable Diesel
IAWG	Interagency Working Group
JCIDS	Joint Capabilities and Integration Development System
LCAC	Landing Craft Air Cushioned

MSC	Military Sealift Command
NAVAIR	Navy Air Systems Command
NAVSEA	Navy Sea Systems Command
NAVSUP	Navy Supply Systems Command
NCT	Naval Coalescence Test
NSTM	Naval Ships Technical Manual
NSWCCD	Naval Surface Warfare Center Carderock Division
OCONUS	Outside the Continental United States
O&M	Operation and Maintenance
OPA	Oil Pollution Abatement Test
RCB-X	Riverine Command Boat
RDT&E	Research, Development, Testing, and Evaluation
RFP	Request for Proposal
RHIB	Rigid-Hull Inflatable Boat
RIMPAC	Rim of the Pacific
RIMSS	Redundant Independent Mechanical Start System
SECNAV	Secretary of the Navy
SWOS	Surface Warfare Officer School
USDA	United States Department of Agriculture
YP	Yard Patrol Craft

ACKNOWLEDGMENTS

I would like to express my sincere gratitude to professors Nussbaum and Fast for taking the time out of their busy schedules to assist me through this process. I would also like to thank my family, friends, and colleagues for all their help and support.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

A. OBJECTIVE

By focusing on the implications of using biofuels in surface ships for doctrine, organization, training, materiel, leadership, personnel, and facilities (DOTMLPF), policy, and cost, this project will help reveal the broader impact of alternative fuel use in the Surface Fleet.

B. BACKGROUND

1. A Brief History of Biofuel

Biological materials, including wood, crops, and vegetables, have been used for fuel since antiquity. By the 19th century, with the spread of the internal combustion engine, petroleum became a source of fuel to power ships, locomotives, and automobiles (Encyclopædia Britannica, 2012). However, many engineering luminaries from that era, including Rudolf Diesel and Henry Ford, recognized that biofuel still had a place in the industrialized world. In the 1890s, Diesel designed an engine capable of running on peanut oil (Specht, 2011, p. 3). Over a quarter of a century later, in an interview with the *New York Times*, Henry Ford predicted that biofuels would supplant petroleum as the primary fuel for automobiles (Michgan State University, 2012).

During World War II, the shortage of petroleum necessitated increased biofuel consumption to support the war effort. The Germans used fuel generated from alcohol and potatoes, while the British used a biofuel mixture consisting of grain alcohol and petroleum (Specht, 2011, p. 4). In the latter part of the 20th century, global events like the 1973 and 1979 oil crises and first and second Gulf Wars drove up petroleum prices and accelerated the need for alternative forms of energy for national and international economic stability and security (Specht, 2011, p. 5).

In addition to economic and security issues, there are environmental reasons for using biofuel. In the latter part of the 20th century, an upsurge in pollution and global temperatures have many turning to biofuels as an alternative to petroleum because biofuels omit less greenhouse gas, are easily biodegradable, and require no drilling (Department of the Navy, Navy Fuels Great Green Fleet, 2011, p. 19).

Figure 1 shows the most recently available breakdown of energy consumption by source in the U.S. by category. Renewable energy, including biofuels, was at 9.1 percent.

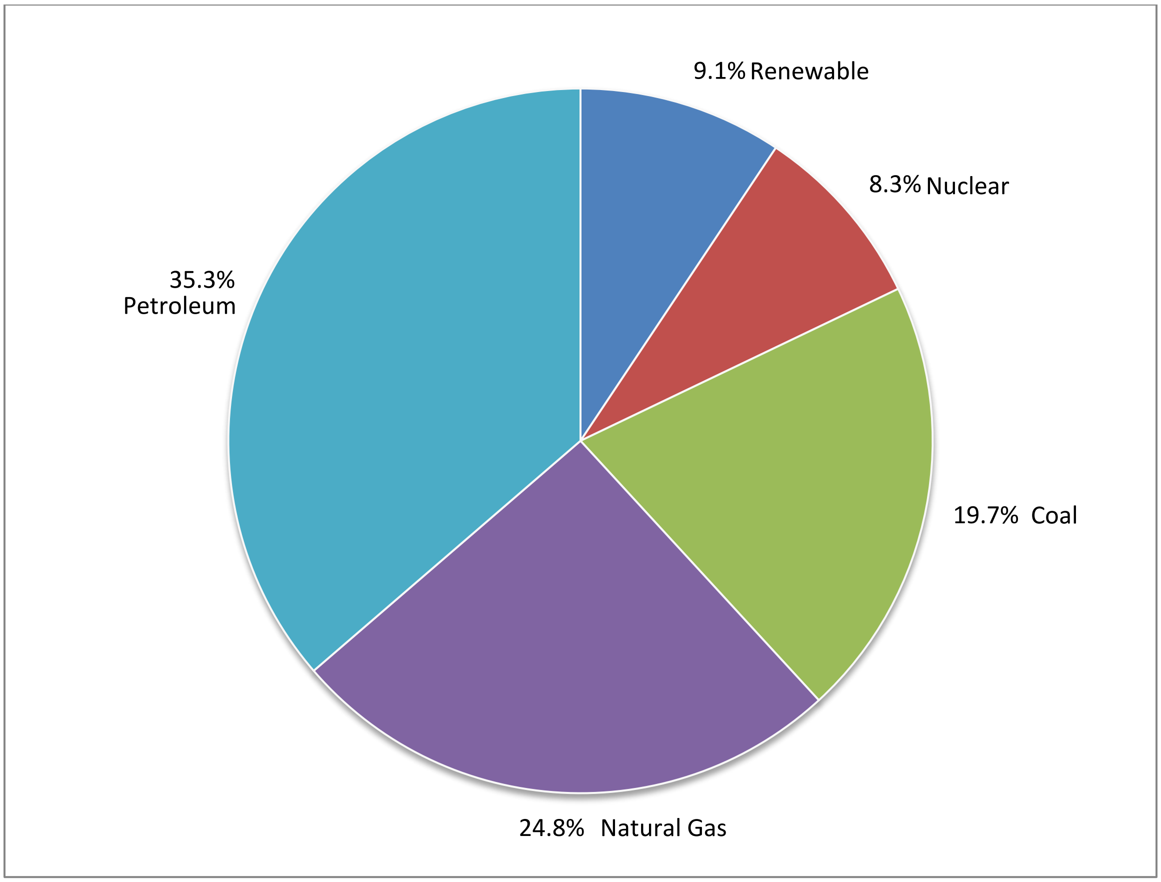

Figure 1. Primary Energy Consumption by Source in 2011 (From EIA Annual Energy Review, 2011)

2. Classifying Biofuels

According to the United States Department of Agriculture (USDA), biofuels comprise a "wide range of fuels which are in some way derived from biomass. The term covers solid biomass, liquid fuels and various biogases" (Department of Agriculture). More simply put, biofuel is derived from once living organisms, including plants, algae, and sugar cane (Department of Defense, Opportunities for DoD, 2010, pp. 1–4 to 1–5). This project addresses the liquid form of biofuel.

Federal legislation, regulation, and policy place liquid biofuel into three categories.

> Alternative fuels are transportation or mobility fuels not composed of or derived from liquid petroleum, including renewable and synthetic fuels. These fuels include petroleum liquid and alcohol blends containing 15 percent or less of petroleum that are pursuant to standard seasonal fuel specifications.
>
> Renewable fuels are transportation or mobility fuels, used alone or blended with petroleum-based fuel and wholly derived from biomass or its decay products. (This term can also refer to petroleum-blended fuel with a renewable component above a certain percentage of “neat” renewable fuel products, such as when B20 is termed biodiesel.)
>
> Synthetic fuels are liquid hydrocarbon fuels produced from coal, natural gas, or, increasingly, biomass. (Department of Defense, Opportunitites for DoD, 2010, p. 1–3).

Biofuels are also classified in three generations. The first generation of biofuel includes soybean oil, vegetable oil, animal fats, and restaurant grease, which account for most of the biofuel in use today (Department of Defense, Opportunities for DoD, 2010, pp. 6–7 to 6–8). The second generation of biofuel comes from cellulosic diesel feed stocks, including corn stover, timber wastes, and dedicated energy crops such as switchgrass. The technology to refine biofuel from cellulosic material is still in the early phases. However, it is expected to develop dramatically during the next ten years (Department of Defense, Opportunitites for DoD, 2010, p. 6–13). The third generation of biofuel is produced from algae feedstock, including diatoms, green algae, golden-brown algae, prymnesiophytes, eustigmatophytes, and cyanobacteria (Department of Defense, Opportunities for DoD, 2010, pp. 6–13).

Algae feedstock is just one of many types of the biofuel the Navy is considering to use in its alternative fuel formula, which is a 50/50 blend of biofuel and petroleum. The Navy chose algae as a biofuel because, compared with corn and soybeans, it can be produced at ten times the rate per acre. Additionally, algae crops can be grown anywhere, require only brackish water, and do not compete with food crops like other biofuel feedstocks (Department of the Navy, Navy Surges, 2012, pp. 18–19).

Table 1 shows the relative yield per acre of algae compared with other biofuel crops.

Crop	Oil yield (gal/acre/year)
Corn	18
Soybean	48
Canola	127
Jatropha	202
Coconut	287
Oil Palm	635
Algae	1,000 – 4,000

Table 1. Biofuel Yields from Various Feedstocks (From NDAA FY10 Sec 334, 2010)

3. DoD and DON Alternative Energy Program

The 2009 Duncan Hunter National Defense Authorization Act formally authorized the Department of Defense (DoD) to begin procuring alternative fuels for military operations (United States Congress, 2009). With Congressional authority, each military branch began developing service-specific alternative energy programs. The following year, in the 2010 National Security Strategy, President Obama outlined the need for United States energy independence. He argued that best way of achieving energy independence is through the development of domestically produced alternative energy resources (Callahan, 2011, pp. 1–3).

The Navy's Alternative Energy goals go hand-in-hand with the President's goals of energy independence and security. The Navy's goals are guided by milestones set forth in 2009 by the Secretary of the Navy (SECNAV), Ray Maybus. These milestones include energy efficient acquisition, deploying a Carrier Strike Group (CSG) of non-fossil fueled ships and aircraft in 2016, reducing non-tactical petroleum use by 2015, increasing alternative energy ashore by 2020, and achieving 50 percent alternative energy consumption for the Department of the Navy (DON) by 2020 (Department of the Navy, Energy Program, 2010, p. 3).

Figure 2 outlines the five goals set forth by the SECNAV for the Navy's Alternative Energy Program.

Figure 2. The Secretary of the Navy's Energy Goals (From DON's Energy Program for Security and Independence, 2010)

The Office of the Assistant Secretary of the Navy for Energy, Installations, and Environment is responsible for promulgating policy to ensure these milestones are met. The office's quarterly publication, *Currents Magazine*, informs key stakeholders (sailors, contractors, elected officials, and the general public) of major developments in the Navy's Alternative Energy Program.

4. Shipboard Replacement Drop-In Biofuel System

The shipboard replacement drop-in biofuel system is the Surface Navy's answer to achieving the SECNAV's energy goals. The system is unique in that it does not require any materiel modifications to ships. The only modification is to the actual fuel being used. Instead of using military marine diesel fuel (F-76), the replacement drop-in system uses a 50/50 biofuel/petroleum blend. In order for biofuel blends to be accepted as an alternative fuel source, it must meet the following criteria:

- It must be a drop-in replacement for the petroleum based fuel.
- It must meet or exceed the performance requirements of the petroleum-based fuel. (There must be no notable operational differences.)
- The biofuel must be able to be successfully mixed or alternated with petroleum fuel.
- The biofuel must require no modifications or enhancements to the configuration of the aircraft or ship.
- The biofuel must require no modifications or enhancements to the Navy's existing fuel storage infrastructure (Department of the Navy, Navy Surges, p. 8)

Navy Air Systems Command (NAVAIR) is in charge of testing and evaluating the replacement drop-in biofuel system for the entire Navy. The agency responsible for testing and evaluating how well the replacement drop-in biofuel system works onboard ships is Navy Sea Systems Command (NAVSEA). Within NAVSEA, the Ship Integrity and Performance Group develop standardized qualification criteria and test various alternative fuels onboard surface ships. The Marine Engineering Group supports the Performance Group by reviewing testing protocol and concurrence for fuel tests (Navy Sea Systems Command, 2012).

NAVSEA also conducts sea trials using the replacement drop-in biofuel system. In November 2011, the decommissioned cruiser USS Paul Foster (DD 964) conducted sea trials from San Diego to Port Hueneme, California using the 50/50 blend. According to NAVSEA, "this was the largest-to-date shipboard alternative fuel demonstration" (Navy Sea Systems Command, 2012).

The demonstration was the latest in a series of “live” Navy tests of the replacement drop-in biofuel system. The Navy first tested the 50/50 blend in a rigid-hull inflatable boat (RHIB) in July 2010. After a successful demonstration, the Navy tested the fuel on several other platforms including a Riverine Command Boat (RCB-X) out of Norfolk, Virginia, a yard patrol craft (YP) at the Naval Academy, and a landing craft air cushioned (LCAC) in Panama City, Florida (Department of the Navy, Navy Surges, 2012, pp. 13–15).

In December 2011, the Navy made headlines when the Defense Logistics Agency (DLA) purchased 450,000 gallons of biofuel to use in July 2012 during the Rim of the Pacific Naval Exercises (RIMPAC) (Parrish, 2011). This exercise is the largest operational test to-date of the shipboard replacement drop-in biofuel system (Department of the Navy, Navy Surges, 2012, p. 15). The data from the tests the Navy has been conducting on biofuel blends are examined in Chapter IV.

THIS PAGE INTENTIONALLY LEFT BLANK

II. LITERATURE REVIEW

This MBA project is the first known DOTMLPF analysis of the Navy's Alternative Energy Program for surface ships. However, there are several published reports, articles, and theses relating to alternative energy use in the DoD and Navy, including "DoD's Alternative Fuels: A Business Case Assessment (BCA) – Version 1.0," "The Navy Biofuel Initiative Under the Defense Production Act," "A Study of Alternative Fuel Impacts to Navy Fueling Infrastructure," "The Great Green Fleet: The U.S. Navy and Fossil-Fuel Alternatives," and "A Cost Estimation of Biofuels for Naval Aviation: Budgeting for the Great Green Fleet." They are summarized below.

A. "DOD'S ALTERNATIVE FUELS: A BUSINESS CASE ASSESSMENT (BCA) – VERSION 1.0"

Paul A. Griffith, Captain, United States Air Force – DLA Energy

This report is a BCA for DLA that assesses the production requirements for using alternative fuels within the DoD and commercial aviation industry. In 2010, both DLA "and the Air Transport Association of America (ATA) entered into a Strategic Alliance to leverage their collective purchasing power to encourage suppliers to bring commercial aviation alternative fuels into the marketplace" (Griffith, 2011, p. 5). Griffith analyzes planned refining capabilities and projected costs for domestically produced alternative fuels in both industries. Griffith finds the following:

1. The DoD lacks an overarching energy strategy that includes plans to pursue alternative fuels.
2. Executing Service-specific goals (at different alternative/petroleum blend percentages) could be extremely costly.
3. Purchasing alternative fuels may have little or no stabilization affect [sic] on the budgeting process of bulk fuels.
4. In the majority of areas examined if currently planned biorefinery programs progress according to plans, there should be enough alternative jet and marine diesel produced to meet a significant portion of DoD's and the commercial airline industry's planned requirements (Griffith, 2011, p. 47).

The report makes the following recommendations for a plan of action to move the DoD and the commercial aviation industry's alternative energy programs forward:

1. Amend Title 10 to allow DoD to enter into contracts for alternative fuel beyond five years.
2. The DoD should join the Biofuels Interagency Working Group (IAWG) currently co-chaired by DOE and USDA.
3. The DoD should immediately partner with USDA's Rural Development Office and DOE's Loan Guarantee Office to influence award decisions to match DoD and commercial-partner requirements.
4. The DoD should partner with alternative fuel producers to influence the mix of fuels in planned facilities to maximize the amount of jet fuel produced. (Griffith, 2011, pp. 47–48)

B. "THE NAVY BIOFUEL INITIATIVE UNDER THE DEFENSE PRODUCTION ACT"

Anthony Andrews, Kelsi Bracmort, Jared T. Brown, and Daniel H. Else – Congressional Research Service

This report to Congress examines whether the Navy, along with the DOE and USDA, should invest in domestic biofuel production in the name of national security. In 2011, the three agencies entered into a memorandum of understanding to "assist the development and support of a sustainable commercial biofuels industry" (Andrews, Bracmort, Brown, & Else, 2012, p. 1). The three departments are expected to invest a combined total of $510 billion over three years to fund large scale production projects to support federal alternative energy initiatives such as the Great Green Fleet (Andrews, Bracmort, Brown, & Else, 2012).

The Defense Production Act (DPA) is one conduit the Navy is using to invest in biofuel production. The DPA authorizes the federal government to invest in alternative energy resources for national security purposes (Andrews, Bracmort, Brown, & Else, 2012, p. 1). However, the report debates whether the federal government should use DPA funding to invest in the domestic biofuel industry. It points out that U.S. dependence on fossil fuel is not as great a threat to national security as some alternative energy proponents suggest. The U.S. only imports 49 percent of its petroleum, of which 25 percent comes from Canada (Andrews, Bracmort, Brown, & Else, 2012, p. 17).

Additionally, the U.S. Energy Information Agency (EIA) projects that U.S. petroleum production could reach 6.7 million barrels per day by 2020 (a level not seen since 1994) (Andrews, Bracmort, Brown, & Else, 2012, p. 18). The report also dispels concerns associated with the U.S. shipping oil revenue overseas to hostile nations and terrorists. In fact, the only major oil exporter hostile towards the U.S. is Iran, which is currently under sanction (Andrews, Bracmort, Brown, & Else, 2012, p. 18).

The report ends by noting that previous alternative energy initiatives were abandoned when new, improved, and inexpensive means of refining and procuring petroleum were discovered. Even if a successful domestic biofuel industry is developed with DPA funds, it will still have to compete with traditional sources of fuel for long term DoD contracts (Andrews, Bracmort, Brown, & Else, 2012, p. 19).

C. "A STUDY OF ALTERNATIVE FUEL IMPACTS TO NAVY FUELING INFRASTRUCTURE"

Armstrong et al. – NPS Technical Report

This technical report provides an in depth analysis of the infrastructure and logistical requirements that must be in place to support deploying a Green Strike Group (GSG) in 2016. These requirements relate to the DOTMLPF categories of organization and facilities. The report assumes the deployment will be a typical six-month deployment from Norfolk, Virginia to the Arabian Gulf (Armstrong et al., 2010, p. iii). Using twelve criteria, the research team determines that Fischer–Tropsch S-5 (FT S-5) jet fuel is the preferred alternative fuel source to be used in the GSG (Armstrong et al., 2010, p. xiii).

The report concludes that it is possible for the Navy to sail a GSG (Armstrong et al., 2010, p. 96). However, significant investment in alternative energy development and infrastructure will be necessary for a successful deployment. Specifically, the research group offers the following recommendations:

- The Navy should determine the alternative fuel that will power the GSG immediately. This study identified several characteristics of alternative fuels that will have an impact on the fueling infrastructure, including reduced energy density. This, for instance, drives the need for additional storage which in turn requires significant construction costs. Identifying the fuel now will reduce the risk to sailing the GSG in 2016, allowing time to assess the infrastructure impacts and account for necessary changes in the appropriate [DoD] budget cycle.

- The Navy should concurrently decide on a GSG mission and identify the sites or manner in which the alternative fuel will be stored.
- The Navy should consider a phased approach to implementing an alternative fuel for the GSG. The research conducted during this study indicates that alternative fuels made from a biomass feedstock, that could substantially improve life cycle green house gas emissions, are considered higher risk to be available in sufficient and affordable quantity by 2016. However, there are fuels, such as the FT S-5 with coal as a feedstock, that have price projections comparable to F-76, and are lower risk to be available in sufficient quantity by 2016. Thus, it may be preferable to initially sail the GSG with an interim source of FT S-5 and switch to a "greener" FT S-5 when affordable. (Armstrong et al., 2010, p. 96)

D. "THE GREAT GREEN FLEET: THE U.S. NAVY AND FOSSIL–FUEL ALTERNATIVES"

Alaina M. Chambers, Lieutenant, United States Navy, and Steve A. Yetiv – Navy War College Review

In this article, Chambers and Yetiv summarize the DoD and Navy's view that fossil fuel dependence creates a vulnerable atmosphere for national security. The problem is compounded by the threats of global warming and emerging industrialized powers, such as China. To counter these vulnerabilities and threats, the DoD and Navy are seeking alternative sources for energy. The authors examine these sources and the opportunities they present.

For tactical platforms, including ships and aircraft, the Navy is developing alternative fuels from algae and camelina (Chambers & Yetiv, 2011, pp. 66–67). The Navy is also seeking energy efficient technological solutions such as building more gas turbine ships and transitioning to hybrid-electric propulsion systems in the Arleigh Burke Class Destroyer (Chambers & Yetiv, 2011, pp. 67–68). In non-tactical platforms, the Navy is promoting the use of alternative fueled vehicles such as flex fueled cars and trucks (Chambers & Yetiv, 2011, p. 69). Ashore, the Navy is looking at ways to generate electricity from ocean power and to conserve energy through the use of energy efficient light bulbs (Chambers & Yetiv, 2011, pp. 70–71).

The article suggests that the DoD and Navy's shift towards energy independence will be minimal unless the public changes its consumption behavior. They conclude that benefits of shifting to more sustainable forms of energy will outweigh long term costs because it creates jobs and opportunities in the private sector in addition to strengthening national security (Chambers & Yetiv, 2011, p. 74).

E. "A COST ESTIMATION OF BIOFUELS FOR NAVAL AVIATION: BUDGETING FOR THE GREAT GREEN FLEET"

Michael D. Callahan, Commander, United States Navy – NPS Thesis

Callahan's thesis estimates the costs of implementing the Navy's Alternative Energy Program for Naval Aviation. He estimates the cost to operate a Carrier Air Wing (CVW) in the Great Green Fleet using alternative jet fuel (Callahan, 2011, p. 19). The Great Green Fleet includes:

- one nuclear Carrier (CVN)
- one nuclear Submarine (SSN)
- one Cruiser (CG)
- two Destroyers (DDG)
- one Air Wing (CVW).

Callahan concludes that "continued growth of a U.S. based biofuel industry may decrease U.S. dependency of foreign petroleum" (Callahan, 2011, p. 53). His estimates of the projected premium cost of blended biofuel for Navy Aviation includes a pessimistic estimation of $3.7 million to fill the fueling requirements of a CVW in the Great Green Fleet in 2016. He forecasts the cost of deploying a CVW in 2020 using blended biofuel during six months for pessimistic, likely, and optimistic scenarios at $71.3 million, $12.1 million, and $30.9 million, respectively (Callahan, 2011, p. 53).

THIS PAGE INTENTIONALLY LEFT BLANK

III. METHODOLOGY

A. APPROACH

This project uses DOTMLPF criteria from the Joint Capabilities Integration and Development System (JCIDS) to analyze the impact of using biofuels onboard surface ships. To conduct the analysis, we take the following approach:

1. Define DOTMLPF
2. Identify which classes of ships and biofuel blend to analyze
3. Determine how each DOTMLPF category will be analyzed

1. Defining DOTMLPF

DOTMLPF is a tool used in the defense acquisition community to identify and propose changes necessary to fill a capability gap for a new system or program. Below is the definition for each element of the DOTMLPF acronym.

- Doctrine. The way we fight, e.g., emphasizing maneuver warfare combined air-ground campaigns
- Organization. How we organize to fight; divisions, air wings, Marine-Air Ground Task Forces (MAGTFs), etc.
- Training. How we prepare to fight tactically; basic training to advanced individual training, various types of unit training, joint exercises, etc.
- Materiel. All the "stuff" necessary to equip our forces, that is, weapons, spares, etc., so they can operate effectively
- Leadership and education. How we prepare our leaders to lead the fight from squad leader to 4-star general/admiral; professional development
- Personnel. Availability of qualified people for peacetime, wartime, and various contingency operations
- Facilities. Real property; installations and industrial facilities (e.g., government-owned ammunition production facilities) that support our forces. (Department of Defense, DOTMLPF Analysis, 2012)

Although the Navy's Alternative Energy Program is not a DoD acquisition program, conducting a DOTMLPF analysis on the replacement drop-in biofuel system will help us to anticipate its impact on the Surface Fleet as well as identify potential shortfalls that might accompany the transition to alternative energy.

2. Identifying the Appropriate Classes of Ships and Biofuel Blend to Analyze

The Navy has tested various biofuel blends on a number of surface platforms, ranging from a seven-meter RHIB to the 529-foot long USS Paul Foster (DD 964). Conducting a DOTMLPF analysis on every ship in the Navy's arsenal is beyond the scope of one MBA project. This project focuses on the following platforms:

- Ticonderoga Class Guided Missile Cruiser (CG)
- Arleigh Burke Class Guided Missile Destroyer (DDG)

Both classes of ships are important components to the Surface Navy. Currently, the Navy has 19 CGs and 60 DDGs, with plans to commission an additional 15 DDGs (Department of Defense, DoD Announces, 2011). The CG and DDG also took part in the Navy's demonstration of the Great Green Fleet during RIMPAC 2012. During the exercise, the Navy delivered 900,000 gallons of 50/50 biofuel/petroleum blended fuel to the Nimitz Carrier Strike Group (CSG), including 700,000 gallons to USS Princeton (CG 59), USS Chaffee (DDG 90), and USS Chung-Hoon (DDG 93) (Burford, 2012).

The fuel we will analyze is HRD-76 blended with F-76 (blended HRD-76), which is an algae-based biofuel blended with marine diesel fuel. HRD-76 is hydro-processed to eliminate water so it can work well with shipboard systems (Department of the Navy, Navy Fuels Great Green Fleet, 2011, p. 19). Because the CG, DDG, and blended HRD-76 were components of the Navy's Great Green Fleet demonstration, all three are used for this DOTMLPF analysis. The data gathered from all three of these components permits us to infer the impact of biofuel use on other surface ships and the Surface Fleet as a whole.

3. Determining How Each DOTMLPF Category Will Be Analyzed

This project identifies items within each DOTMLPF category that will be impacted by transitioning to blended HRD-76 onboard a CG/DDG. Not all categories will be impacted the same, and some will not be impacted at all.

The first category to be examined is doctrine. Rather than focusing on "the way we fight," this project focuses on "the way we fuel" and whether current fueling doctrine is sufficient to support the replacement drop-in biofuel system. The best starting point for Navy fuel doctrine for surface ships is the Naval Ships Technical Manual (NSTM) Chapter 541, *Ship Fuel and Fuel Systems*. This publication provides doctrine and policy to shipboard personnel on how to store, handle, and test fuel. If blended HRD-76 or any other alternative fuel requires personnel to alter the way they handle and test fuel, then the NSTM as well as other appropriate publications and instructions will have to be updated and modified.

The second DOTMLPF category is organization. Since blended HRD-76 is considered a drop-in fuel, current shipboard organization will not be modified to accommodate transitioning from F-76. However, beyond the shipboard organizational level, intergovernmental agency coordination is necessary to provide fuel to naval forces deployed around the world. This effort is undertaken DLA, Navy Supply Systems Command (NAVSUP), and Military Sealift Command (MSC).

DLA is responsible for procuring fuel through its energy branch (DLA Energy), with capital from the Defense Working Capital Fund (Armstrong et al., 2010, p. 27). Once the fuel is procured, it is sent to one of the 135 world-wide Defense Fuel Supply Points (DFSP) that resupply naval forces (Armstrong et al., 2010, p. 27).

NAVSUP is the agency responsible for distributing fuel procured by DLA to ships. NAVSUP coordinates with DLA Energy to "receive, store, issue, maintain quality, and account for bulk liquid fuel and lubricating oils supplied to Navy ships" (Armstrong et al., 2010, p. 29). Under NAVSUP there are seven regional fleet logistics centers (FLC) that distribute fuel to ships (Department of the Navy, NAVSUP Global).

- NAVSUP Fleet Logistics Center Jacksonville
- NAVSUP Fleet Logistics Center Norfolk
- NAVSUP Fleet Logistics Center Pearl Harbor
- NAVSUP Fleet Logistics Center Puget Sound
- NAVSUP Fleet Logistics Center San Diego
- NAVSUP Fleet Logistics Center Sigonella
- NAVSUP Fleet Logistics Center Yokosuka

The FLCs operate deep water bulk fuel storage terminals. Ships inport can fuel directly at these terminals, or barges can transfer fuel from the terminals to ships berthed at naval bases (Armstrong et al., 2010, pp. 30–31). Afloat, MSC transfers fuel from the DFSPs to ships through a process known as underway replenishment (Armstrong et al., 2010, p. 35).

Figure 3 illustrates the organizational relationship between DLA, NAVSUP, and MSC that supports refueling ships around the world.

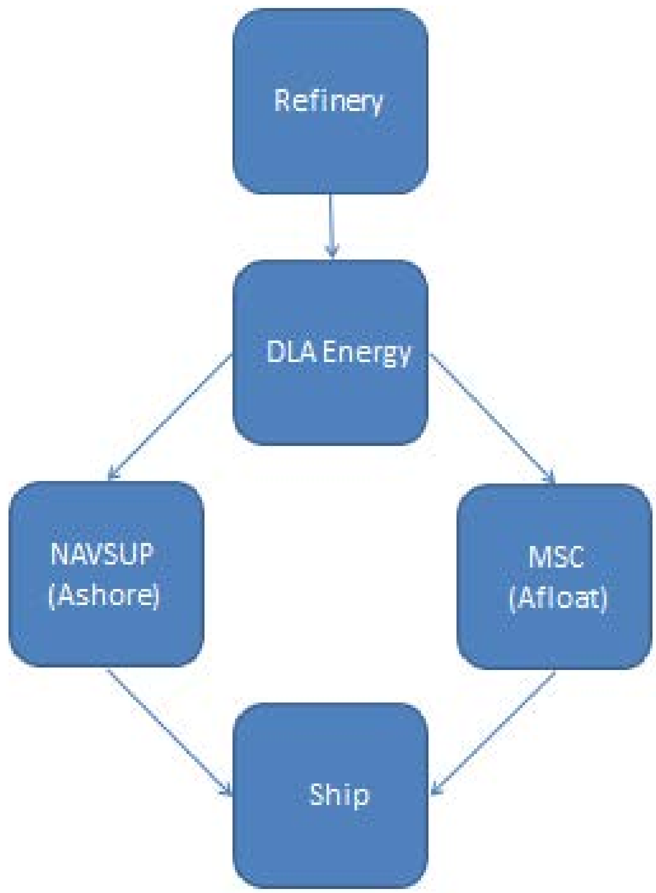

Figure 3. Organizational Relationship Between DLA, NAVSUP, and MSC.

Fuel at the DFSPs is procured by DLA from local refineries, which means DFSPs outside the continental United States (OCONUS) receive fuel from foreign refineries (Armstrong et al., 2010, p. 38). This can be problematic if the Navy intends to deploy ships overseas using blended HRD-76 or other biofuel products, because there is no assurance that these types of fuel will be available OCONUS. This project examines whether international biofuel production is capable of supporting ships deployed with the replacement drop-in biofuel system overseas. It also discusses whether the current organizational relationship between DLA, NAVSUP, and MSC is sufficient for supplying naval forces around the world with biofuel.

The next DOTMLPF category is training. Sailors receive training on handling and testing fuel at the Navy Fuels School located in the Fleet Concentration Areas. There, they learn how to test F-76 for contaminates such as solids and water, which can build up and affect the material condition of a ship. Contaminated fuel undergoes a “settling and stripping” process through the ship’s purification system (Integrated Publishing). Testing procedures for F-76 are found in NTSM Chapter 541. If the testing procedures for blended HRD-76 and other alternative fuels differ from F-76, then the Navy will have to modify the NSTM and train sailors on new testing procedures for biofuel. This project examines the physical and chemical properties of blended HRD-76 and compares it to F-76 to see if new testing procedures are required.

Table 2 outlines the current testing procedures for F-76.

Name of Test	Equipment (methods)
Visual	Glass sample bottle
Bottom sediment and water (BS&M)	Laboratory centrifuge
Flashpoint	Pensky-Martens closed-cup tester
API gravity	Hydrometer range: 29–41 and 39–51

Table 2. Required Shipboard Fuel Testing Procedures for F-76 (From Integrated Publishing).

The fourth DOTMLPF category is materiel. We have already seen how ships test fuel for contaminants that can be harmful to equipment. In the next chapter, we assess whether blended HRD-76 has more contaminants than F-76, and the long term materiel and maintenance impact onboard ships. Additionally, the project compares the flash points of blended HRD-76 and F-76 to see if the biofuel mix poses a greater threat of flashing into a Class Bravo Fire (a fire fueled by combustible liquids).

The fifth category is leadership. Shipboard leaders, and especially the Commanding Officer, Executive Officer, and Chief Engineer, must have a clear understanding of the full impact of using alternative energy onboard. This will require that they be updated on new policies, training requirements, and the materiel implications of using biofuel blends. More than likely, they will receive their training at the Surface Warfare Officer School (SWOS) in Newport, Rhode Island. This project accesses whether the SWOS curriculum should be updated to prepare shipboard leaders for transitioning to the replacement drop-in biofuel system, particularly in the Department Head School and CO/XO courses.

The next DOTMLPF category is personnel. Since blended HRD-76 is a drop-in replacement for F-76, and no other shipboard element, then there will be no need for additional manning or enlisted classifications to store, handle, or test the fuel.

The final DOTMLPF category is facilities. This project analyzes the current facilities and infrastructure for storing and transferring fuel, including tanks and trucks, and examines if they are adequate for biofuel blends such as HRD-76.

Figure 4 shows the current fueling infrastructure for ships in the continental United States (CONUS) and OCONUS.

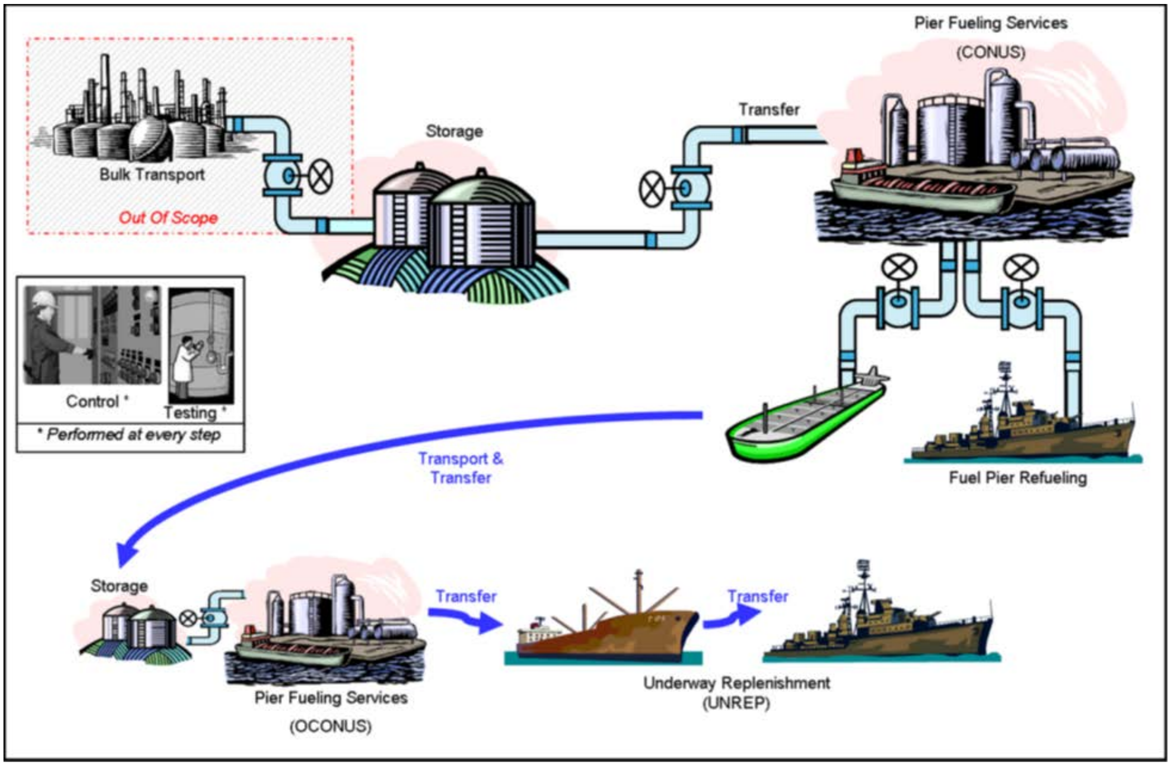

Figure 4. Existing Navy Fueling Infrastructure High-level Operational Concept (From A Study of Alternative Fuel Impacts to Navy Fueling Infrastructure, 2010).

In addition to the categories discussed above, this project examines the policy (a newly-added category to DOTMLPF) and cost implications of using biofuel in surface ships. We look at the current administration, DoD, and Congressional policy as well as the price of biofuel to see if it supports the Navy's alternative energy goals. Data for this project will be collected from scholarly sources and from the DON, NAVSEA, NAVSUP, DLA, and other pertinent government agencies.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. DATA AND ANALYSIS

In this chapter, we use data taken from various tests conducted on blended HRD-76 to analyze its physical and chemical properties and evaluate its impact on each DOTMLPF category for a CG and DDG. We also look at the policy and cost implications of adopting biofuels to use onboard ships. The findings are summarized at the end of the chapter in a "stop light" chart.

A. TESTING AND ANALYZING BLENDED HRD-76

In order for a biofuel blend to be certified as an alternative fuel in the Navy, it must undergo a series of preliminary tests.

Figure 5 illustrates each stage of testing required for an alternative fuel to be certified for military specification.

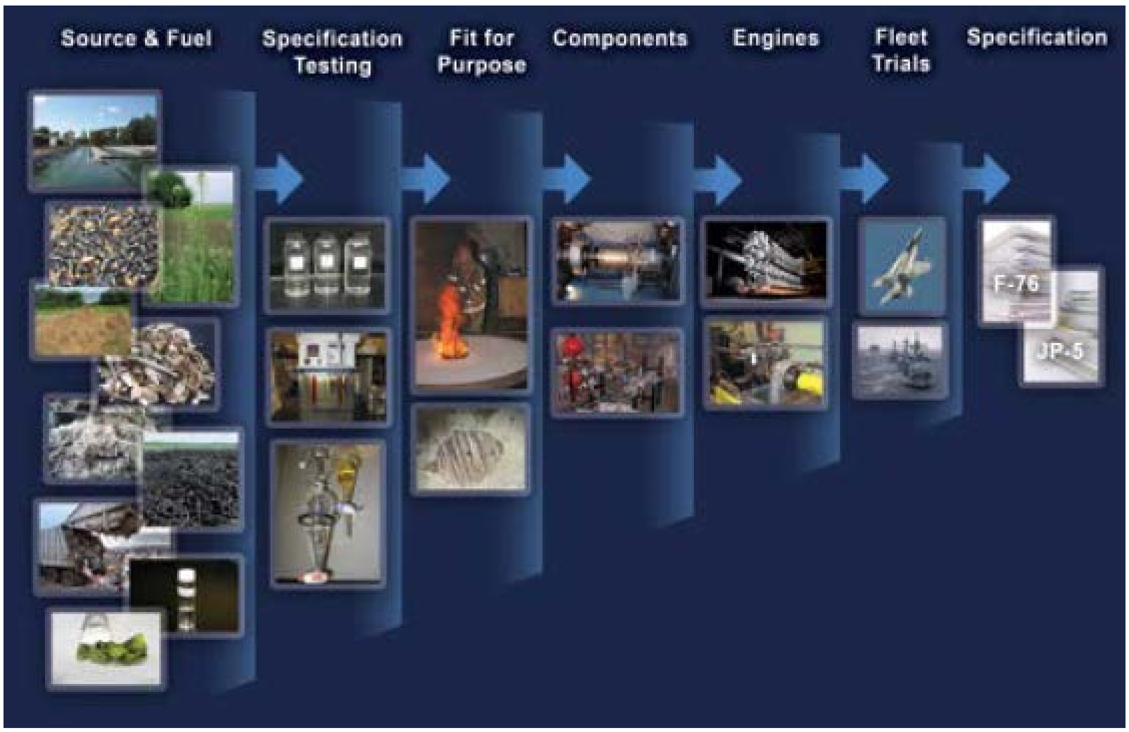

Figure 5. From Field to Fleet: Certifying Drop-In Replacements (From U.S. Navy Biofuel Test and Qualification Update, 2012).

We examine data taken from the following tests the Navy conducted on blended HRD-76:

- Specification Testing
- Fit-for-Purpose Testing
- Engine Component Testing
- Full Scale Engine Testing

Blended HRD-76 must meet the same criteria for F-76 in each of these tests in order to be certified as a replacement drop-in biofuel.

Specification Testing. During specification testing, an alternative fuel candidate must undergo a series of tests and evaluations to ensure it meets procurement/military specifications for F-76. Specifications for F-76 are found in MIL-DTL-16884. MIL-DTL-16884 outlines requirements for "fuel properties that are critical to performance, handling and shipboard safety" that must be met before a batch of F-76 can be delivered to the DoD (Eldridge, Kamin, Leung, Turgeon, & Williams, 2011, p. 3). The Navy successfully tested a batch of blended HRD-76 using the same criteria.

Table 3 shows the average specification test results for HRD-76. The last column shows that blended HRD-76 falls within the minimum/maximum range of accepted criteria for F-76 in all categories (Eldridge, Kamin, Leung, Turgeon, & Williams, 2011, p. 9).

Test	Parameter	Method	Units	Minimum	Maximum	Average Neat HR-76	Average HR-76/petroleum F-76
Appearance		D4176	-----	Clear & Bright		clear & bright	clear & bright
Demulsification		D1401	minutes		10	1	2.25
Density at 15°C		D1319	kg/m^3		876	779	811
Distillation	10% Recovered	D86	°C	Report		251	217
	50% Recovered	D86	°C	Report		285	275
	90 % Recovered	D86	°C		357	295	303
	End Point	D86	°C		385	307	330
	Residue	D86	Volume %			1.8	1.775
Cloud Point		D5773	°C		-1	-4	-12
Color		D1500	-----		3	0	L 1.5
Flash Point		D93	°C	60		82	69
Particulate		D6217	mg/L		10	0	2
Pour Point		D5949	°C		-6	-11	-18.75
Viscosity at 40°C		D445	cSt	1.7	4.3	2.9	2.6
Acid Number		D974	mgKOH/g		0.30	0.01	0.06
Ash		D482	Mass %		0.005	0.000	0.000
Carbon Residue on 10%		D524	Mass %		0.20	0.03	0.09
Copper Strip Corrosion		D130	-----		1	1b	1a
Hydrogen Content		D7171	Mass %	12.5		14.9	13.9
Ignition Quality	Derived Cetane	D613	-----	42		74	60
	Cetane Index	D976	-----	43		77	63
Storage Stability, total		D5304	-----		3	0	0.4875
Sulfur, Total	XRF or,	D4294	Mass %		0.50	N/A	0.09
	UV Fluorescence	D5453	ppm		5000	0	N/A
Trace Metals	Calcium	D7111	ppm		1.0	< 0.1	< 0.1
	Lead	D7111	ppm		0.5	<0.1	<0.1
	Sodium + Potassium	D7111	ppm		1.0	0.3	0.841
	Vanadium	D7111	ppm		0.5	< 0.1	< 0.1

Table 3. Specification Testing Results for Neat HRD, Blended HRD-F76 and F-76 (From Overview of U.S. Navy's Ships Renewable Fuels Evaluation, 2011)

Fit-for-Purpose (FFP) Testing. FFP testing is critical to the overall certification process because it looks for chemical and physical properties found in blended HRD-76 that are not typically measured for petroleum. These properties have the potential to impact performance, materials compatibility, handling, and safety of the fuel (Eldridge, Kamin, Leung, Turgeon, & Williams, 2011, p. 4). Blended HRD-76 completed this stage of testing with no impact to its performance or materials compatibility (Department of the Navy, U.S. Navy Biofuel, 2012, p. 6). As far as safety was concerned, blended HRD-76 was tested using various shipboard firefighting agents, including Halon 1301, hepatafluoropropane (HFP), aqueous film forming foam (AFFF), high expansion foam, and water mist. There was no difference in how these agents performed on blended HRD-76 and F-76 (Department of the Navy, U.S. Navy Biofuel, 2012, p. 6).

It is important to note that unblended or "neat" HRD-76 would not pass this stage of testing, which is why the Navy blends it with F-76. Blending biofuel with petroleum allows it meet FFP properties for aromatics, cetane, lubricity, and density, all of which are critical to performance (Eldridge, Kamin, Leung, Turgeon, & Williams, 2011, p. 10).

Figure 6 displays the FFP testing results for blended HRD-76 under each category analyzed. Checkmarks indicate a complete/successful test. As of March 2012, FFP testing is still ongoing for materials (turbine hot section, metallic, and non-metallic).

Figure 6. Blended HRD-76 Fit-for-Purpose Testing Results (From U.S. Navy Biofuel Test and Qualification Update, 2012)

Blended HRD-76 also passed the Naval Coalescence Test (NCT) and Oil Pollution Abatement (OPA) Test. The NCT determines "if there are any potential negative impacts to the filter coalescer or separator that would cause excess water to pass through the filtration system" (Eldridge, Kamin, Leung, Turgeon, & Williams, 2011, p. 11). The OPA test uses several devices (such as the oil content monitor, oil water separator, foam generation miscibility and oil content determined by EPA 1664 Protocol) to detect and separate spilled oil from water as well as foaming characteristics. These tests detected no differences between blended HRD-76 and F-76 (Eldridge, Kamin, Leung, Turgeon, & Williams, 2011, pp. 11–12).

Engine Component Testing. Engine component testing measures how alternative fuels like blended HRD-76 perform on marine gas turbine, diesel, and boiler engine components, including shipboard quality assurance instruments, fuel injector nozzles, fuel nozzle atomization, fuel nozzle fouling, carbon deposition, ignition and stability, thermal performance, fuel system block valves leakage, and burner sprayer plate capacity and performance (Eldridge, Kamin, Leung, Turgeon, & Williams, 2011, p. 7).

Table 4 lists the results from component testing conducted on various diesel engine fuel injectors using blended HRD-76. The results of these tests show no impact to the injectors that completed testing (testing on the Caterpillar 3500 injector was still ongoing as of the last available report in March 2012).

Make/Model	Results
Caterpillar 3500	In progress
Fairbanks Morse 38D 8–1/8	No Impact
MTU 396	No Impact
Yanmar L	No Impact
Paxman RP 200	No Impact

Table 4. Diesel Injector Component Testing (From U.S. Navy Biofuel Test and Qualification Update, 2012).

Full Scale Engine Testing. The Navy has been conducting full scale engine tests with blended HRD-76 on both gas turbine and diesel engines. Because the CG and DDG under analysis in this project both use gas turbine engines for propulsion and electricity generation, we include the results and data from the gas turbine engine tests.

The Navy conducted the gas turbine engine test on the Rolls Royce 501-K34 electric generator and its starter, the 250-KS4 redundant independent mechanical start system (RIMSS). This same engine combination is found on all Flight 2A DDGs (hull number 79 and above) (Karpovitch). The test was conducted in January 2011 at the DDG 51 Land Based Engineering Site located at the Naval Surface Warfare Center Carderock Division (NSWCCD) in Pennsylvania (Lueng, Quiñones, & William, 2012, p. 1). A total of seven test cycles were performed on both the 501-K34 and the 250-KS4. The first test cycle was conducted using F-76 in order to establish a baseline for data analysis; the remaining six were conducted using blended HRD-76. Each test lasted for 7 hours and 20 minutes and included 21 load scenarios. It took 44 hours to complete the series of tests (Lueng, Quiñones, & William, 2012, p. 1). The results of these tests were published in the report: *Algae Based Hydroprocessed Fuel Use on a Marine Gas Turbine*.

During the tests, the Navy examined “parameters for combustion temperature, fuel demand, fuel manifold pressure, engine start time, and operation under various load conditions” (Lueng, Quiñones, & William, 2012, p. 1). The 250-K34 started consistently within the 60 second time frame requirement using blended HRD-76 without incident (Lueng, Quiñones, & William, 2012, p. 3). However, data taken from the tests conducted on the 501-K34 were less conclusive. For one, the engine started faster with blended HRD-76 than it did with F-76. However, each successive start using blended HRD-76 took longer than the previous one (five seconds between the first and sixth start). The report suggests this may be attributed to ambient day temperature, but the evidence was inconclusive (Lueng, Quiñones, & William, 2012, p. 3). There were also erratic temperature readings and spreads on the 501-K34 throughout the tests. However, the report says these were not due to the alternative fuel but rather to clogged fuel filter elements and engine components (Lueng, Quiñones, & William, 2012, p. 11).

One promising finding from the tests is that blended HRD-76 produces fewer emissions than F-76, which is beneficial to the environment (Lueng, Quiñones, & William, 2012, p. 10). Table 5 shows the average emissions during the full scale engine tests.

Parameter	O_2 (%)	CO_2 (%)	CO (ppm)	NOx (ppm)	THC (ppm)
F-76	17.00	2.48	4.75	154.09	1.56
Alt. Fuel – Cycle 1	16.83	2.46	3.98	148.37	1.71
Alt. Fuel - Cycle 2	17.03	2.39	4.21	142.91	1.05
Alt. Fuel – Cycle 4	17.04	2.40	3.52	145.63	0.95
Alt. Fuel - Cycle 5	17.02	2.41	3.84	146.57	1.83

Table 5. F-76 and HRD-76/F-76 Alternative Fuel Average Emission Measurements (From Algae Based Hydroprocessed Fuel Use on a Marine Gas Turbine, 2012).

In light of these findings, NSWCCD recommends gathering more data to support certifying blended HRD-76 by testing it for an additional 14,000 to 22,000 hours, which is the average time marine engines operate before being overhauled (Lueng, Quiñones, & William, 2012, p. 11).

In addition to the preliminary tests discussed above, the Navy also tested blended HRD-76 onboard various surface platforms, including the guided missile frigate (FFG) USS Ford (FFG 54). Like the CG and DDG, FFGs are powered by gas turbine engines. The ship’s crew conducted routine fueling evolutions using blended HRD-76 including fuel onload, tank readings, filtration, sampling, and testing. They reported no difference to shipboard operations (Department of the Navy, Navy Biofuel, 2012, p. 11). It is evident from these series of tests that blended HRD-76 is compatible to F-76.

B. EVALUATING THE IMPACT OF BLENDED HRD-76 ON EACH DOTMLPF CATEGORY

What does the data from these preliminary tests say about the DOTMLPF implications of using blended HRD-76 onboard a CG or DDG? The results from specification and FFP testing show that the chemical and physical properties of blended HRD-76 are very similar to F-76, while component, full scale engine, and platform testing indicate the alternative fuel will have little impact on performance and shipboard operations. This implies that the DOTMLPF categories of doctrine, training, leadership, personnel, and facilities will minimally be impacted by transitioning from F-76 to blended HRD-76 onboard a CG/DDG. Blended HRD-76 did not alter the way shipboard personnel stored, handled, or tested fuel onboard USS Ford (FFG 54) and other platforms evaluated. It seems likely that the data from the CG and two DDGs in the RIMPAC 2012 exercise will confirm these findings.

Shipboard leaders and sailors will have to be aware of the finite differences (e.g., flash point and emissions) between the F-76 and blended HRD-76. These differences should be highlighted and added to current fueling publications and instructions as well as curricula in applicable fueling, engineering schools, and SWOS. As far as facilities are concerned, since blended HRD-76's physical and chemical properties are similar to F-76, both fuels can be stored and transferred in the same containers and tanks, both afloat and ashore. Additionally, the Navy intends on procuring HRD-76 that is already blended with F-76, requiring no additional facilities or equipment for mixing the two fuels.

Let us now turn to the DOTMLPF categories of organization and materiel. As mentioned in the previous chapter, shipboard organization onboard a CG/DDG will not be impacted by a replacement drop-in biofuel. However, the organizations responsible for delivering fuel to ships will be moderately impacted by the availability of a key ingredient to blended HRD-76, algae-based biofuel. These organizations will need to determine whether algae-based biofuel will be available in large enough quantities to be mixed with F-76 and delivered to multiple ships operating around the world.

Currently, the Navy procures algae-based biofuel through DLA, which submits request for proposals (RFP) to commercial biofuel vendors on the Federal Business Opportunities website (http://www.fedbizopps.gov). The RFPs specify the amount of fuel the Navy is requesting, how much it intends to pay for it, and by when it needs it to be delivered. While most of the current vendors are domestic, DLA will eventually have to procure algae-based biofuel from local vendors OCONUS. This means a thriving international biofuel market is needed to support the Navy's transition to blended HRD-76.

The biofuel market is still in its infancy, both CONUS and OCONUS, and current algae-based biofuel production is not sufficient for the 1.2 to 1.6 billion gallons of fuel our naval forces consume annually (Jean, 2010). However, the market is growing fast. According to Pike Research data, algae-based biofuel production will reach 61 million gallons per year by 2020, equivalent to an annual growth rate of 72 percent (Wolan, 2011). Most of this growth is expected to occur in North America, Europe, and Asia. Production in the Africa/Middle East region, where the Navy operates extensively, is projected to remain stagnant.

Figure 7 shows projected algae based biofuel production grouped by global regions from 2010 to 2020.

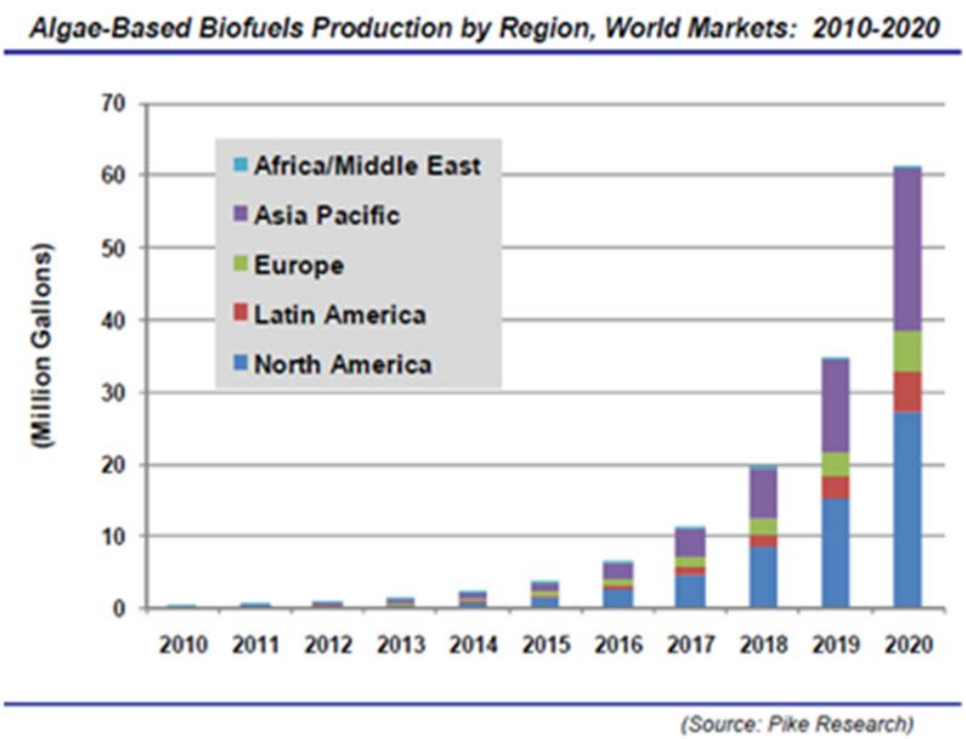

Figure 7. Algae Based Biofuels Production by Region, World Markets: 2010–2020 (From Forbes.com, originally published by Pike Research, 2011)

The procurement of algae-based biofuel to use in HRD-76 will be impacted by the rate of growth in the international biofuel market. DLA must monitor the development of the market and make plans accordingly. The Navy may even have to switch between blended HRD-76 and F-76 depending on the region in which it is operating. DLA, NAVSUP, and MSC must be ready to adapt to these regional differences if the Navy transitions to blended HRD-76. The three organizations have demonstrated that they can work together to deliver blended HRD-76 to the CGs and DDGs participating in the RIMPAC 2012 demonstration. The Navy should apply the logistical lessons learned from this and future exercises involving the movement of alternative fuels (CONUS and OCONUS) to fully evaluate the organizational impact of using replacement drop-in biofuels.

From a materiel perspective, we see indications that blended HRD-76 can perform as well as F-76 on shipboard systems. All of the components, engines, and platforms tested were able to operate with the alternative fuel. Also, blended HRD-76 is just as safe, if not safer than F-76 in marine environments, as shown by its high flashpoint. However, to determine the long term materiel impact of using blended HRD-76 onboard a CG/DDG, the Navy must increase its sample size by testing more engines for longer periods of time, and insure against hardware and environmental factors that might inadvertently affect the data (as in the case of the 501-K34 engine test).

C. POLICY AND COST IMPLICATIONS OF USING BIOFUEL

Having completed the DOTMLPF analysis, we turn to the broader policy and cost implications of using blended HRD-76 and other biofuel products onboard surface ships. We begin this portion of the analysis by looking at how much the Navy is currently spending to procure and test alternative fuel. The Navy's budget estimates for fiscal year (FY) 2013 shows funding for alternative fuel procurement and testing in two budget categories: Operation and Maintenance (O&M) and Research, Development, Testing, and Evaluation (RDT&E). Since the Navy uses fuel to conduct daily operations and training, all fuel procurement falls under the O&M category. For FY 2013, the Navy is estimating its ships will consume 7.7 million barrels of fossil fuel, which will cost approximately $1.2 billion[1] (Department of Defense, Operation and Maintenance, 2012, p. 336).

The Navy accounts for the cost of biofuel in its FY 2013 fuel budget but does not specify a dollar amount. In 2012, the Navy spent $12 million while in 2010 it only spent $8.5 million for biofuel procurement (Cichon, 2011). As noted above, the Navy purchases biofuel from private companies through DLA. DLA has entered into contracts with several biofuel vendors including Dynamic Fuels, which is a partnership between Tyson Foods and Syntroleum Corporation (Cichon, 2011).

In addition to O&M, the Navy is requesting $55.3 million for the Navy Energy Program, which falls under RDT&E (Department of Defense, RDT&E, 2012, pp. N-4A). Unfortunately, the Navy does not indicate whether money from this budget category is allocated for alternative fuel testing and evaluation, and it is difficult estimate a dollar amount. The Air Force, on the other hand, has a line item its RDT&E budget dedicated to "alternative fuels." The Navy should follow suit and include line items for alternative fuel procurement and testing in its O&M and RDT&E budgets to make it easier to identify how much the program will cost on an annual basis.

The fact the Navy does not have line items in its budget specifying how much it spends on alternative fuel procurement and RDT&E can be problematic. How does the Navy expect stakeholders to buy into the program if it is not apparent how much it spends on an annual basis? This apparent lack of transparency is also found in other areas of the program. For example, the Navy intends to replenish ships with its 50/50 biofuel blend without informing crews they are taking on non-petrol fuel. This may be due to the fact that it can be difficult to track fuel type from DFSP to ship. However, to prevent an atmosphere of mistrust between the user and Navy energy officials, the Navy should make every effort to track the HRD-76 it delivers to ships and inform the crews that they are taking on alternative fuel. In turn, crews can provide feedback, data, and lessons learned on how blended HRD-76 impacts shipboard operations.

[1] This approximation is calculated by multiplying the amount fuel naval ships are expected to consume in FY 2013 (7.7 million barrels) by the DOD Customer Fuel price for a barrel of F-76 ($156.24 per barrel).

There is also the question of whether the Navy's Alternative Energy Program will survive the current political and fiscal environment in Washington, DC. Many elected officials believe the DoD has invested too much in alternative energy development and the program should be reduced. In May 2012, the Senate Arms Services Committee drafted a bill that would effectively eliminate biofuel spending within the DoD. The bill prevents the "production or purchase of an alternative fuel if the cost of producing or purchasing the alternative fuel exceeds the cost of traditional fossil fuel" (Munoz, 2012). Since biofuel is more expensive per gallon than fossil fuel, the Navy will not be authorized to purchase biofuel beginning in 2013 if this bill becomes law.

The primary reason why biofuel is more expensive than fossil fuel is due to simple supply and demand economics. Right now biofuel costs the Navy, on average, $26.60 per gallon, while petroleum costs $3.72 per gallon (Department of Defense, Operation and Maintenance, 2012, p. 197). Mixing biofuel with petroleum drops the price down to $16 per gallon (Beidel, 2012). However, biofuel blends are still four times more expensive than petroleum. There simply is not enough demand to offset the cost of biofuel, which is high due to the fact there are not enough refineries producing it. The USDA estimates that in order for biofuel production to reach a sustainable peak of 36 billion gallons by 2020, there will need to be an investment of $168 billion in infrastructure development (Beidel, 2012). However, the DoD and DON cannot be the sole investors in biofuel production. There needs to be more commercial investment, not only in the domestic biofuel market, but also internationally, if biofuels are going to compete with fossil fuels in terms of cost.

D. DOTMLPF/POLICY AND COST STOP LIGHT CHART FOR THE SHIPBOARD REPLACEMENT DROP-IN BIOFUEL SYSTEM

Figure 8 is a stop light chart displaying the impact blended HRD-76 will have on each DOTMLPF category, as well as the cost and policy implications of using biofuel in surface ships.

Doctrine **Minimal Impact**	G
Organization **No impact to shipboard organization. Organizations responsible for delivering fuel to ships will be moderately impacted by the availability of algae-based biofuel worldwide.**	Y
Training **Minimal Impact**	G
Materiel **Specification, FFP, component, and full scale engine testing indicate blended HRD-76 can perform as well on shipboard systems as F-76. However, more testing needs to be conducted before we can access its long term materiel impact.**	Y
Leadership **Minimal Impact**	G
Personnel **Minimal Impact**	G
Facilities **Minimal Impact**	G
Policy **Proposed legislation has the potential to stop biofuel procurement if it is more expensive than petroleum.**	R
Cost **The high cost of biofuel in relation to fossil fuel will significantly impact the Navy's ability to procure it.**	R

= "Green" Minimal Impact

= "Yellow" Moderate Impact

= "Red" High Impact

Figure 8. DOTMLPF/Policy and Cost Stop Light Chart for the Shipboard Replacement Drop-In Biofuel System.

THIS PAGE INTENTIONALLY LEFT BLANK

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Blended HRD-76 has minimal impact on the CG and DDG platforms for most DOTMLPF categories analyzed. Although this project only focused on one type of biofuel blend for two classes of ships, it provides an indication of what the overall impact of transitioning to alternative fuels will be.

The data indicates that using replacement drop-in biofuels in surface ships is feasible with a few questions to be answered in order for the transition to be successful. First, how does the Navy intend to sustain ships with alternative fuel sources that are not readily available throughout the world? Second, what is the long term materiel impact of using alternative fuels onboard ships? The Navy needs to continue testing and evaluating alternative fuels on shipboard components, engines, and platforms to increase the sample size and the data on drop-in biofuels.

Finally, there are many policy and cost implications for using alternative fuels onboard surface ships. From a policy perspective, there are potential issues when it comes to the program's budget and execution. The Navy should make clear to all stakeholders how much it spends on biofuel procurement and testing as well as inform crews every time ships take on alternative fuel. There is also the potential for Congress to enact legislation that would effectively prohibit the Navy from procuring biofuel. Lastly, the current price of biofuel is a barrier that must be overcome if biofuels are ever going to compete with petroleum. The Navy must also look at ways to ensure its own policies and investments help, rather than hinder, its overall alternative energy goals.

B. RECOMMENDATIONS FOR FURTHER RESEARCH

Below is a list of subjects not addressed by this MBA project. Because these topics have the potential to impact alternative fuel use and development for the Navy, they deserve further study and therefore can be the basis for future research:

- Conduct a DOTMLPF on using drop-in biofuels in naval aircraft.
- Conduct a cost effectiveness analysis comparing the full burden costs of adopting alternative fuels in ships and aircraft, including consideration of procurement costs, energy independence and security, and environmental factors.
- Determine which biofuel feedstock is best suited for the Navy's replacement drop-in biofuel system in terms of availability, cost, and compatibility.
- Forecast the prices of petroleum and blended HRD-76 to the year 2020 to identify which type of fuel will cost less in the long run.
- Compare and contrast other alternative energy resources the Navy is considering to use in ships.

LIST OF REFERENCES

Andrews, A., Bracmort, K., Brown, J. T., & Else, D. H. (2012, July 22). *The Navy biofuel initiative under the defense production act.* Washington, DC: Congressional Research Service.

Armstrong, L., Colon, J., Finch, C., Kelly, M., King, J., McCreary, J., et al. (2010). *A study of alternative fuel impacts to navy fueling infrastructure.* Thesis, Naval Postgraduate School, Monterey, CA.

Beidel, E. (2012, June). *Biofuels industry at crossroads as military waits for lower prices (UPDATED).* Retrieved October 12, 2012, from National Defense Magazine website: http://www.nationaldefensemagazine.org/archive/2012/June/Pages/BiofuelsIndustryatCrossroadsasMilitaryWaitsforLowerPrices.aspx

Burford, S. (2012, July 17). *Kaiser delivers biofuel for RIMPAC's great green fleet demo*. Retrieved August 20, 2012, from Navy website: http://www.navy.mil/submit/display.asp?story_id=68410

Callahan, M. D. (2011). *A cost estimation of biofuel for naval aviation: budgeting for the great green fleet.* Thesis, Naval Postgraduate School, Monterey, CA.

Chambers, A. M., & Yetiv, S. A. (2011). The Great Green Fleet: The U.S. Navy and Fossil Fuel Alternatives. *Navy War College Review*, *61*(3), 61–77.

Cichon, M. (2011, December 8). *U.S. navy fuels "green strike force" with $12 million biofuels contract*. Retrieved June 1, 2012, from Renewable Energy World website: http://www.renewableenergyworld.com/rea/news/article/2011/12/u-s-navy-fuels-green-strike-force-with-12-million-biofuels-contract

Department of Agriculture. (n.d.). *Glossary of terms*. Retrieved July 4, 2012, from United States Department of Agriculture website: http://www.usda.gov/energy/matrix/FindTerms

Department of Defense. (2011, July). *Opportunities for DoD use of alternative and renewable fuels: FY 10 NDAA section 334 congressional study.* Washington, DC: Department of Defense.

Department of Defense. (2011, April 15). *DoD announces selected acquisition reports*. Retrieved July 30, 2012, from Department of Defense website: http://www.defense.gov/releases/release.aspx?releaseid=14411

Department of the Defense. (2012). *Operation and maintenance overview: fiscal year 2013 budget estimates.* Retrieved November 29, 2012, Office of the Under Secretary of Defense (Comptroller) website: http://comptroller.defense.gov/defbudget/fy2013/fy2013_OM_Overview.pdf

Department of Defense. (2012). *RDT&E programs (R-1).* Retrieved October 23, 2012, from Office of the Under Secretary of Defense (Comptroller) website: http://comptroller.defense.gov/defbudget/fy2013/fy2013_r1.pdf

Department of Defense. (2012, November 9). *DOTMLPF analysis*. Retrieved August 6, 2012, from Defense Acquisition University website: https://acc.dau.mil/ILC_DOTMLPF

Department of the Navy. (2010). *Department of the Navy's energy program for security and independence.* Retrieved November 19, 2012, from Department of the Navy Energy, Environment, and Climate Change website: http://greenfleet.dodlive.mil/files/2010/04/Naval_Energy_Strategic_Roadmap_100710.pdf

Department of the Navy. (2010). *Navy fuels great green fleet vision: latest milestone on the road to energy security*. Retrieved November 19, 2012, from Department of the Navy Energy, Environment, and Climate Change website: http://greenfleet.dodlive.mil/files/2011/01/Win11_Great_Green_Fleet_Vision.pdf

Department of the Navy. (2012). *Navy surges towards energy independence*. Retrieved November 19, 2012, from Department of the Navy Energy, Environment, and Climate Change website: http://greenfleet.dodlive.mil/files/2012/01/Spr12_Energy_Independence.pdf

Department of the Navy. (2012, March 26). *U.S. navy biofuel qualification update*. Presentation given by Sherry Williams at ABCANZ 2012.

Department of the Navy. (n.d.). *NAVSUP global logistics support (NAVSUP GLS).* Retrieved August 13, 2012, from Navy Supply Systems Command website: http://www.navsup.navy.mil/navsup/ourteam/navsupgls

Eldridge, G., Kamin, R., Leung, R., Turgeon, R., & Williams, S. (2011, October). *Overview of the U.S. navy's ships renewable fuels evaluation.* Presentation given at IASH 2011, the 12TH International Conference on Stability, Handling, Use of Liquid Fuels, Sarasota, FL.

Encyclopedia Britannica. (2012, July 02). *Biofuel*. Retrieved November 19, 2012, from Encyclopedia Britannica website: http://www.britannica.com/EBchecked/topic/967492/biofuel

Griffith, P. (2011). *DoD's alternative fuels: A business case assessment (BCa).* Defense Logistics Agency Operations Research and Resource Analysis (DLA DORRA), Richmond, VA.

Integrated Publishing (n.d.). *Shipboard fuel testing*. Retrieved November 13, 2012, Integrated Publishing website: http://www.tpub.com/engine3/en32–62.htm

Jean, G. V. (2010, April). *Navy's energy reform initiatives raise concerns among shipbuilders*. Retrieved October 22, 2012, from *National Defense Magazine* website: http://www.nationaldefensemagazine.org/archive/2010/April/ Pages/NavyEnergyReformRaiseConcerns.aspx

Karpovitch, E. A. (n.d.). *The green road to energy independence*. Retrieved October 21, 2012, from *Surface Warfare Magazine.* website: http://surfwarmag.ahf.nmci.navy.mil/green_road.html

Lueng, R., Quiñones, M., & William, S. (2012, June 13). *Algae based hydroprocessed fuel use on a marine gas turbine.* Presentation given at the Turbine Technical Conference and Exposition, Copenhagen, Demark.

Michigan State University. (2012, June 7). *Eleven things you probably didn't know about biofuels*. Retrieved 29 June, 2012, from Michigan State University Research website: http://research.msu.edu/stories/ eleven-things-you-probably-didn%E2%80%99t-know-about-biofuels

Munoz, C. (2012, May 25). *Senate blocks biofuel development in draft defense bill*. Retrieved June 7, 2012, from The Hill website: http://thehill.com/blogs/defcon-hill/budget-appropriations/229573-senate-blocks-biofuel-development-in-draft-defense-bill-

Navy Sea Systems Command. (2012). *On watch 2012 keeping america's navy #1: alternative fuels*. Retrieved June 19, 2012, from Navy Sea Systems Command website: http://www.navsea.navy.mil/OnWatch/energy3.html

Norman, E., & Sherin, J. (2012). *Is algae fuel a viable alternative to petroleum?* Retrieved September 29, 2012, from UC San Diego School of Management website: http://rady.ucsd.edu/mba/clubs/rbj/rady-business-journal /2012/algae-fuel/

Parrish, K. (2011, December 5). *Navy to demonstrate biofuel use during exercise*. Retrieved July 2, 2012, from Department of Defense website: http://www.defense.gov/news/newsarticle.aspx?id=66359

Specht, Z. (2011). *Biofuels history and review*. Retrieved November 19, 2012 from San Diego State University website: http://solar.sdsu.edu/EDG_pdf/A%20Biofuels%20History%20and %20Review.pdf

United States Congress. (2009). *Duncan hunter national defense authorization act for fiscal year 2009.* Washington, DC: United States Government Printing Office.

United States Energy Information Administration. (2011). *annual energy review 2011* Retrieved November 4, 2012, from United States Energy Information Agency website http://www.eia.gov/totalenergy/data/annual/pdf/sec2_3.pdf

Wolan, C. (2011, March 9). *Can algae get countries to kick foreign oil?* Retrieved September 29, 2012, from *Forbes* website: http://www.forbes.com/sites/christianwolan/2011/03/09/ can-algae-biofuel-get-america-to-kick-its-foreign-oil-addiction/3/

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Chief of Naval Operations – Fleet Readiness and Logistics (OPNAV N4)
   Pentagon
   Washington, DC

4. Chief of Naval Operations – Resources, Requirements & Assessments (OPNAV N8)
   Pentagon
   Washington, DC

5. Dr. Daniel Nussbaum
   Naval Postgraduate School
   Monterey, California

6. William Fast
   Naval Postgraduate School
   Monterey, California